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#### **PCT**

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*With an international search report.*

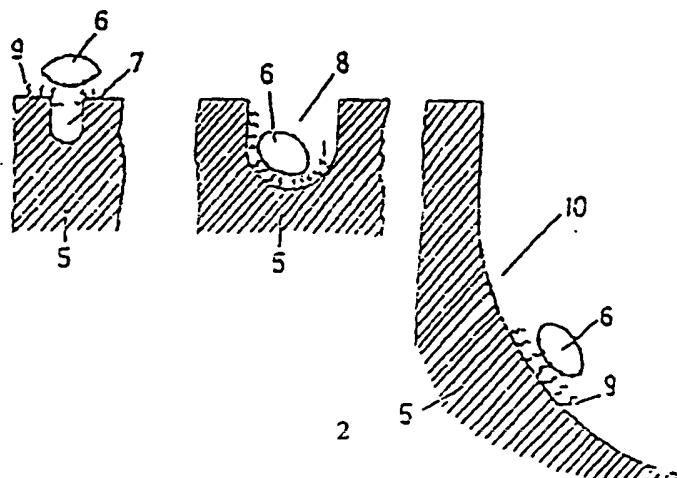
*With modified claims.*

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**(54) Title:** CHROMATOGRAPHIC METHOD FOR ISOLATING MACROMOLECULES

**(57) Abstract:**

Various macromolecular compositions may be separated into their various components by means of a chromatographic method. The interactions of the macromolecules with the chromatographic carrier takes place in monodispersed size cavities with chemically modified surface. To solve a separation problem, a carrier material (5) is selected with cavities (7), (8) of which the diameter is correlated with the dimensions of the macromolecules (6) to be isolated and of which the chemical modification allows an optimum non-covalent interaction with the macromolecule. The interaction is further enhanced by attaching the interconnection groups by flexible chain molecules (9) to the carrier material and by excluding bivalent ions from all solvents.



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## Chromatographic method for separating macromolecules

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The invention pertains to a chromatographic process in which the carrier materials, which contain cavities, and the surface modification of the carrier materials have been optimized for special separating problems. The advances in biochemistry, molecular biology and polymer chemistry and their application in technology, medicine, pharmacy and genetic engineering require the rapid and systematic separation and isolation of macromolecules. Long chain oligonucleotides, high molecular nucleic acids and proteins are of special interest in the biological sciences in this connection. Thus in genetic engineering, for example, the problem frequently arises that a single molecular species has to be purified, to the point of complete homogeneity, from a naturally occurring mixture of 100 or more different high molecular nucleic acids. As is known, the individual nucleic acids can be characterized by their molecular weight, size and shape.

Chromatographic processes have proven to be advantageous for many separating problems. In this connection, high pressure liquid chromatography (HPLC) offers the greatest number of advantages in regard to resolution, low expenditure of time and reproducibility. This method was used previously in the form of gel permeation chromatography (GPC), ion exchange chromatography and reversed phase chromatography (RP chromatography). The following disadvantages arose in this way for the separating problems which are to be dealt with here.

GPC is capable of separating only very small molecules from very large ones.

Previously known ion exchangers and reversed phase carrier materials were capable of being used with high resolution only with small macromolecules such as oligonucleotides, peptides and protein fragments. The required resolution could not be attained for the separation of high molecular macromolecules such as, for example, messenger ribonucleic acids, viruses, viroids, deoxyribonucleic acid fragments and large proteins.

The hydrophobic/ionic chromatographic material RPC-5 such as, for example, that described by Larson, J.E. et al. (The Journal of Biological Chemistry (1979) 254, 5535-5541) was used with success for separating deoxyribonucleic acid fragments but it cannot be adapted to HPLC since the carrier material is not stable with respect to pressure. One therefore has to put up with low flow rates, i.e. very long chromatography times, and low chromatographic stability as disadvantages. It was not possible to separate complex ribonucleic acid mixtures from protein mixtures because of the chemical properties of the RPC-5 material.

Using previously known chromatographic processes, it was not possible, with high resolution and high speed, to separate complex macromolecular mixtures into their individual molecular species and to isolate them or analyze these mixtures.

The invention sets for itself the task of indicating a process and a device with which the aforementioned disadvantages are avoided. In particular, it is required that one be capable of separating -- in a single pass and with very high resolution and at a high rate of throughput -- macromolecular mixtures of the most widely differing types into their components, whereby the mixtures contain components with very different dimensions, e.g. in the range from 30 Å up to 1000 Å. In addition, the materials that are used should be capable of use at high pressure, over wide temperature ranges and with a long life. A high loadability with the macromolecular mixtures, that are to be separated, is desirable. This task is accomplished in accordance with the invention which is described in Claim 1 and the following claims. Thus, in contrast, to the current opinion in the technical literature, a chromatographic process has been developed and the carrier materials, which are necessary for this purpose, have been synthesized with which it is possible to separate -- with a very high resolving capacity -- complex macromolecular mixtures with a very wide spectrum of molecular sizes. Because of its simplicity and the inexpensive and stable materials as well as its economical application, this process is suitable for industrial usage in particular.

In contrast to previously known processes, which depended exclusively on the chemical properties of the carrier materials, the present invention proceeds on the basis of the knowledge that the size and/or shape of the cavities of the carrier materials are of quite essential significance for separation purposes and that they have to bear a certain relationship to the size of the macromolecular species that are to be isolated. It has been found that the size of the cavities has to amount to 1-20 times that of the component which is to be isolated. If the dimensions of the individual components, that are to be separated, differ from one another by more than a factor of 20, then it is, of course, possible to carry out separation in several steps.

A suitable modification of the surface is provided in accordance with an advantageous further development of the invention. In this connection, it has proven to be very advantageous if the groups, which are responsible for the interaction with the substances which are to be separated, are anchored onto the surface via flexible chain molecules. This action is achieved, for example, as a result of the use of g-glycidyloxypropyl-trimethoxysilane and N,N-dimethylaminoethanol. As far as the interacting groups are concerned, consideration can be given to strongly and weakly basic anion exchangers, strongly and weakly acidic cation exchangers, groups with hydrophobic interactions, groups with polarization interactions and groups which combine several of the designated properties.

Since, in the case of many applications, it has been found that bivalent metal ions can give rise to considerable interference, the proposal is also made in accordance with the invention that all parts, which come into contact with the solvents, should consist of a noble metal, plastic or glass or, as the case may be, have appropriate coatings.

The invention is elucidated in more detail on the basis of the figures.

The following aspects are shown.

Figure 1 shows a device, which is known as such, for the implementation of a chromatographic process.

Figure 2 shows sections of cross sections through carrier materials with various sizes of cavities.

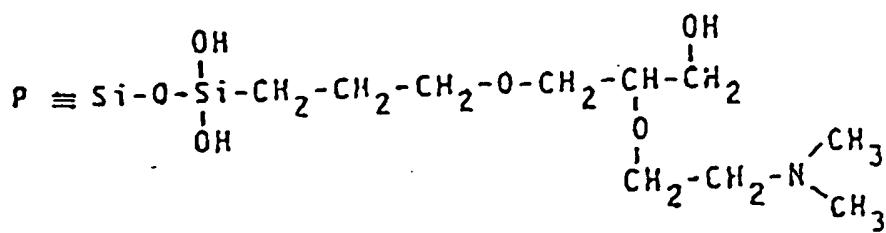
#### Figures

3, 4 and 5 show a graphic representation of various elution profiles for various sizes of cavities and sizes of molecules.

The device, which is illustrated in Figure 1, consists of a pressure-resistant cylinder (2) that is provided with a supply connection unit (1) and a run off connection unit (3). A very fine mesh, chemically inert sieve (4) is arranged in the lower part of the cylinder (2). The chromatographic carrier, that consists of discrete macro-porous silica gel particles (5), is located above the sieve (4). The substances, that are to be separated, are introduced in solution via the supply connection unit (1) and are absorbed in the cavities of the carrier (5). During the subsequent elution step, the substances and molecules, that are to be separated, are eluted via a solvent of continuously varying composition. Because of the change in the solvent over the course of time, the separated components emerge sequentially in the effluent (3) over the course of time.

The effect of the size of the cavities of the carrier material on the interaction with the macromolecule is elucidated on the basis of Figure 2. A macromolecule (6) cannot penetrate satisfactorily into an excessively small cavity (7) of the carrier material (5) in order to enter into optimum interaction. By contrast, the cavity (8), which is more favorable as a result of its dimensions, permits very intensive interactions. In order to increase the interaction, the interacting groups are anchored onto the surface of the cavity via flexible chain molecules (9). If, by contrast, the cavity (10) is too large, then one again has to reckon on a decrease in the interaction. The chain

molecules in this example have the following chemical structure:



The flexible chain g-glycidyloxypropyltrimethoxysilane is anchored on one side on the carrier silica gel (P) and carries the N,N-dimethylamino anion exchange group at its other end.

The chemical modification, that has been described, was used in spherical silica gels with a grain size of 10 mm and cavity sizes of 100 Å, 500 Å and 4000 Å. For this purpose, 50 g of silica gel particles are activated in a 1000 ml three-neck flask for 24 hours at a pressure of < 1 mbar and a temperature of 240°C. After cooling, ventilation took place with dry nitrogen and mixing took place with 500 ml of dry g-glycidyloxypropyltri-methoxysilane. The reaction took place for 8 hours at 220°C under a nitrogen atmosphere together with steady stirring. After the reaction, the excess g-glycidyloxypropyltrimethoxysilane is removed by means of suction and the epoxy-silica product is washed several times with dry dioxane. The epoxy silica was mixed with 500 ml of dry N,N-dimethylaminoethanol using a four-neck flask with an internal thermometer, a reflux condenser, a stirrer and a nitrogen inlet tube. The reaction was catalyzed by means of 1 ml of  $\text{BF}_3$ /ether and boiling took place under reflux for 24 hours. After the reaction, the dimethylamino silica gel was removed by suction and washed several times with dioxane, methanol and ether and then dried at 50°C. The yield amounted to 51.5 g.

Examples of the separation of short chain nucleic acids (Figure 3) and long chain nucleic acids (Figures 4 and 5) are illustrated in Figures 3 through 5. The diameters of the cavities are 100 Å, 500 Å and 4000 Å as indicated in the drawing. The concentration of the eluted components is measured via their UV absorption at 260 nm and is plotted against time.

The following results can be read off. Short chain nucleic acids with a length of 20 Å to 30 Å are separated optimally in a cavity size of 100 Å (Figure 3). As an example of the separation of long chain nucleic acids, we selected a natural mixture of transfer RNA (80 Å size), ribosomal 5SRNA (110 Å size), 9S messenger RNA (300 Å size) and viroid RNA (450 Å size, a plant-based pathogenic infectious RNA). It can be seen clearly from Figure 4 that the largest pore size, which was selected, results in the best separation, whereby the aspect is not ruled out that still better separation could have been achieved with a cavity size which lies between 500 Å and 4000 Å. The example from Figure 4 is further optimized in Figure 5 as a result of slower elution. Complete separation of all four components is achieved.

The dimethylamino silica gels, that were used in the examples that have been given, had a loadability of 4.8 mg of nucleic acid mixture/g (100 Å), 17.2 mg nucleic acid mixture/g (500 Å) and 5.6 mg of nucleic acid mixture/g (4000 Å).

The process, that has been described in accordance with the invention, is the first chromatographic process that has the following properties.

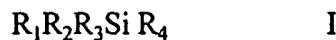
1. General applicability for the separation of macromolecules.
2. Short chromatography times and high reproducibility of the elution profiles as a result of the use of pressure-stable carriers in HPLC devices.
3. High loadability.
4. Chromatography materials with long-term stability (no "bleeding out" of the chromatography columns).

## Patent Claims

1. Chromatographic process for the isolation of macromolecules by using carriers which contain pore-type cavities, characterized by the feature that use is made of a carrier, which contains pore-like cavities, in which the diameters of the cavities have 1-20 times the dimensions of the macromolecules and/or macromolecular aggregates that are to be separated.
2. Process in accordance with Claim 1, characterized by the feature that the size of the cavities is optimized in terms of the largest dimension in each case of the macromolecular species that is to be isolated.
3. Process in accordance with Claim 1, characterized by the feature that the size of the cavities is optimized in terms of the maximum dimensions of the macromolecular species that are contained in the mixture.
4. Process in accordance with Claims 1 through 3, characterized by the feature that the cross sections of the cavities are as constant as possible.
5. Process in accordance with Claims 1 through 3, characterized by the feature that the cross sections of the cavities can be a factor 3 larger or smaller than the optimum cross section.
6. Process in accordance with Claims 1 through 4, characterized by the feature that the cross section of the cavities is circular and the surface is hemispherical.
7. Process in accordance with Claims 1 through 4, characterized by the feature that the cavities are tubular.

8. Process in accordance with one or more of the previously designated claims, characterized by the feature that the solution, which contains the macromolecules which are to be separated, and the elution agents, are kept free from bivalent metal ions, e.g. as a result of the use of a noble metal, glass and/or plastic for the columns, tubes, valves or, as the case may be, pumps.
9. Device for the implementation of the process in accordance with one or more of the Claims 1 through 7, characterized by the feature that the surfaces of the cavities are modified in such a way that non-covalent interactions are ensured with the macromolecules that are to be separated.
10. Device in accordance with one or more of the previously designated claims, characterized by a modification of the surfaces of the hollow cavities that brings about a strongly or weakly basic anionic interaction.
11. Device in accordance with one or more of the previously designated claims, characterized by a modification of the surfaces of the hollow cavities that brings about a strongly or weakly acidic cationic interaction.
12. Device in accordance with one or more of the previously designated claims, characterized by a modification of the surfaces of the cavities which brings about a hydrophobic interaction.
13. Device in accordance with one or more of the previously designated claims, characterized by a modification of the surfaces of the cavities which brings about a polarization interaction.
14. Device in accordance with one or more of the previously designated claims, characterized by a combination of the interactions which are designated in Claims 9 through 13.

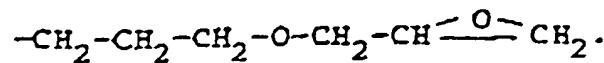
15. Device in accordance with one or more of the previously designated claims, characterized by the feature that the modification of the surfaces of the cavities takes place by means of a chemical substance which carries groups of flexible chain molecules which are responsible for the interaction.
16. Device in accordance with one or more of the previously designated claims, characterized by the feature that the carrier, which forms the cavities, consists of spherical or fragmented materials with a cavity size of 100 Å to 10,000 Å and a specific surface of 10 m<sup>2</sup>/g to 800 m<sup>2</sup>/g and, especially, between 500 Å to 4000 Å with a specific surface of 5 m<sup>2</sup>/g to 200 m<sup>2</sup>/g and a grain size, which is as monodisperse as possible, between 3 mm and 100 mm.
17. Device in accordance with one or more of the previously designated claims, characterized by the feature that the carriers, which have the cavities, can consist of silicon dioxide, whether this be amorphous or crystalline, aluminosilicates, aluminum oxides or carrier substances which have been coated with these materials.
18. Device for the [type of] preparation in accordance with Claims 9 through 17, characterized by the following steps:
  - a) the carrier material which contains hollow cavities is reacted with a silanizing reagent of general formula



$R_1$  corresponds to an alkoxy residue with 1 to 10 C-atoms, especially -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub> or -OC<sub>3</sub>H<sub>7</sub>, or a halogen atom, especially -Cl, or a dialkylamino group with identical or different alkyl residues with 1 to 6 C-atoms.

R<sub>2</sub> and R<sub>3</sub> correspond to a hydrocarbon residue with 1 to 10 C-atoms, especially -CH<sub>3</sub>, -C<sub>2</sub>H<sub>5</sub> or -C<sub>3</sub>H<sub>7</sub> or an alkoxy residue with 1 to 10 C-atoms, especially -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub> or -OC<sub>3</sub>H<sub>7</sub>, or a halogen atom or an alkyl residue with 4 to 20 C-atoms, whereby the alkyl residue is interrupted by at least one oxa group or amino group and whereby this residue can also be substituted singly or multiply by a halogen group, a cyano group, a nitro group, an amino group, a monoalkylamino group, a dialkylamino group, a hydroxy group or an aryl group.

R<sub>4</sub> corresponds to a hydrocarbon chain with 1 to 20 C-atoms or to an alkyl residue, which is interrupted by at least one oxa group or amino group, whereby this residue can also be singly or multiply substituted with a halogen group, a cyano group, a nitro group, an amino group, a monoalkylamino group, a dialkylamino group, an alkoxy group, a hydroxy group, an aryl and/or an epoxy group, especially



b) In a second step, the carrier, that contains the cavities, is reacted with a reagent of general formula



to give the final chromatography material. X consists of an amino group, a hydroxy group, an epoxy group or a halogen atom.

R consists of a hydrocarbon chain with 2 to 20 C-atoms or an alkyl residue which has been interrupted by at least one oxa group or amino group, whereby this residue can also be substituted singly or multiply by a halogen group, a cyano group, a nitro

group, an amino group, a monoalkylamino group, a dialkylamino group, an alkoxy group, a hydroxy group, an aryl group and/or an epoxy group.

Y corresponds to a hydrocarbon residue with functional groups with 1 to 10 C-atoms, whereby the functional groups form anion exchangers or cation exchangers and which can be substituted singly or multiply by amino groups, monoalkylamino groups, dialkylamino groups, quaternary alkylamino groups, carboxyl groups, boric acid, alkylsulfonic acid and arylsulfonic acid.

## MODIFIED CLAIMS

[received at the International Office on August 30, 1983 (08.30.83); the original Claim 1 is replaced by the new Claim 1 whose text follows. The original Claims 2 through 18 remain unchanged].

1. Chromatographic process for the isolation and analysis of macromolecules, especially nucleic acids and proteins, by using carriers which contain pore-type cavities, characterized by the feature that use is made of a carrier, which contains pore-like cavities, in which the diameters of the cavities have 1-20 times the dimensions of the macromolecules and/or macromolecular aggregates that are to be separated and the surfaces of the cavities are suitable for physical interaction with the macromolecules which are to be separated.

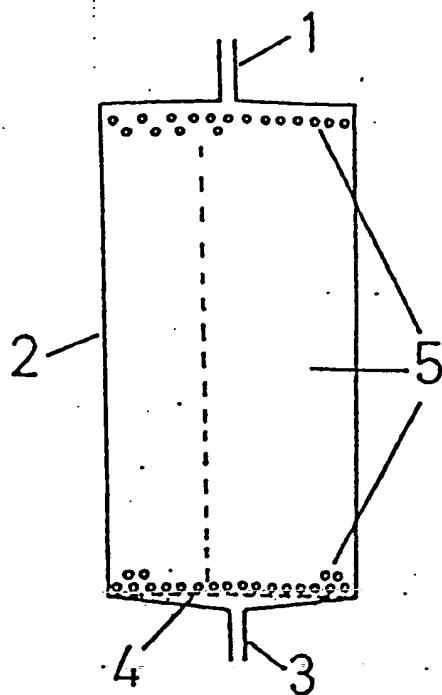


Fig. 1

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OF

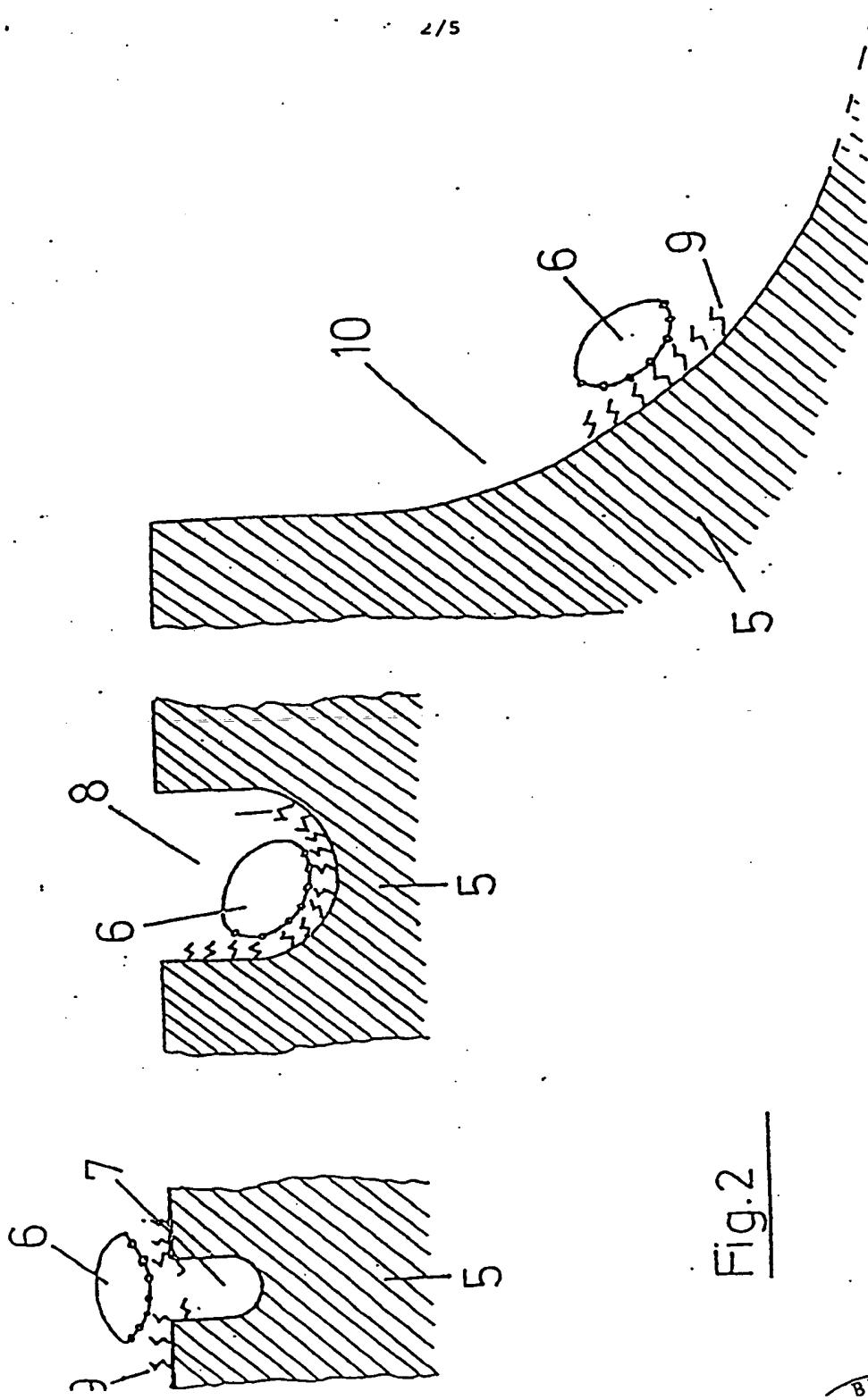


Fig. 2

BUREAU

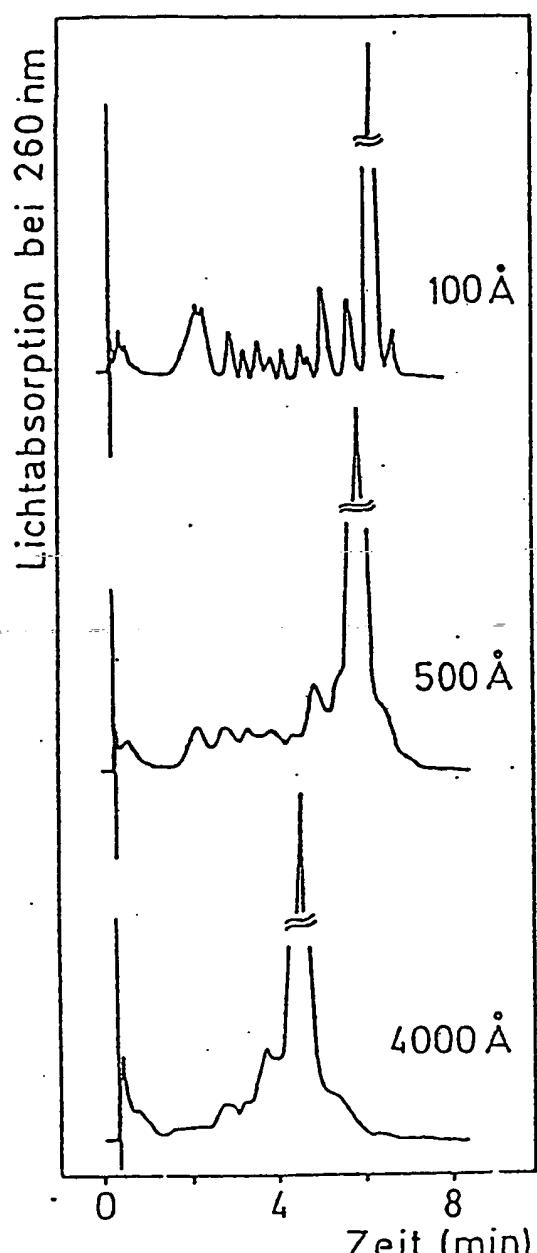
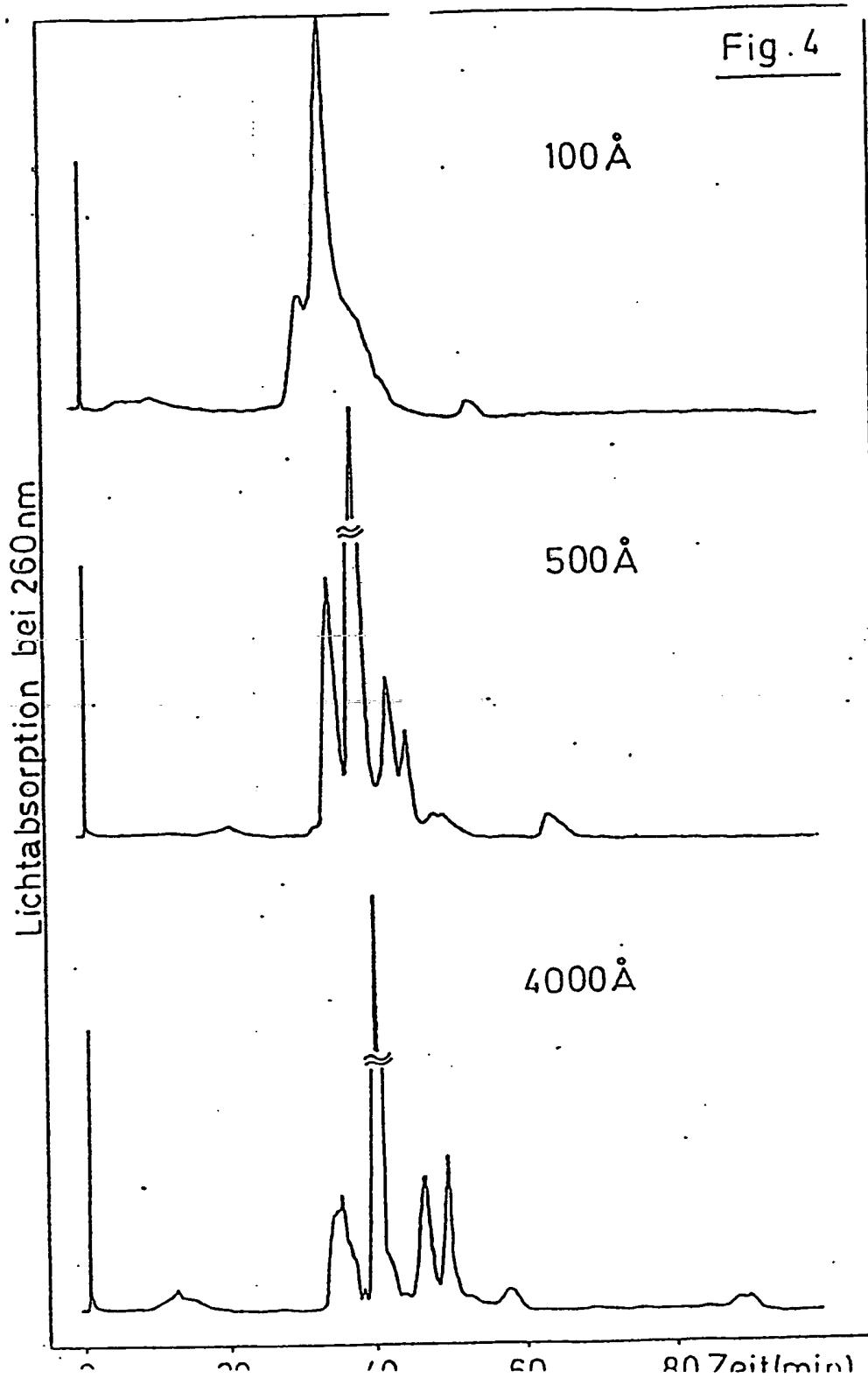


Fig. 3

BUREAU  
OMPI

Fig. 4



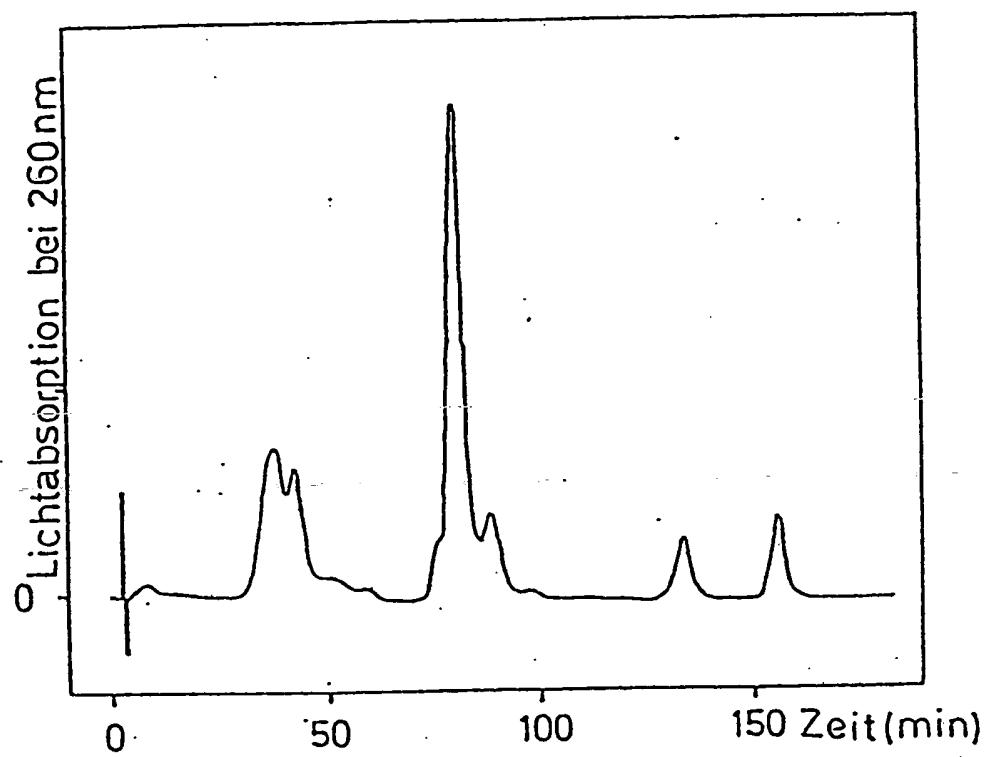


Fig.5

BUREAU  
MPI

# INTERNATIONAL SEARCH REPORT

International Application No PCT/DE 83/000 56

## I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) <sup>3</sup>

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl.<sup>3</sup> B 01 D 15/08; B 01 J 20/30; G 01 N 31/06

## II. FIELDS SEARCHED

Minimum Documentation Searched <sup>4</sup>

Classification System	Classification Symbols
Int.Cl. <sup>3</sup>	B 01 D; B 01 J

Documentation Searched other than Minimum Documentation  
to the Extent that such Documents are Included in the Fields Searched <sup>5</sup>

## III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>14</sup>

Category <sup>6</sup>	Citation of Document, <sup>14</sup> with indication, where appropriate, of the relevant passages <sup>15</sup>	Relevant to Claim No. <sup>16</sup>
X	DE, A, 2601930 (U.K.A.B.A.) 21 July 1977, see page 13, line 12 - page 19, line 22; pages 31-34, examples 9-10	1,2,9,16,17
Y	US, A, 4029583 (HO CHANG) 14 June 1977, see column 4, line 5 - column 16, line 47	1,9-18
Y	GB, A, 2075362 (KURARA,Y ) 18 November 1981; see page 1, lines 42-53, line 62, page 4, example 1; page 7, example 8, page 10, claims 1-25	1-6,9-18
A	US, A, 4118316 (TAILEY) 03 October 1978, see columns 8-12; claims 1-17	1,9,10,16-18
A	US, A, 4140653 (IMURA) 20 February 1979, see columns 6-8; claims 1-9	1,9,11
A	FR, A, 2462183 (MERK PATENT) 13 February 1981, see pages 25-26; claims 1-3	1,9,12

\* Special categories of cited documents: <sup>15</sup>

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"A" document member of the same patent family

## IV. CERTIFICATION

Date of the Actual Completion of the International Search <sup>17</sup>	Date of Mailing of this International Search Report <sup>18</sup>
17 June 1983 (17.06.83)	15 July 1983 (15.07.83)
International Searching Authority <sup>19</sup> European Patent Office	Signature of Authorized Officer <sup>20</sup>

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 12/07/83

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A- 2601930	21/07/77	None	
US-A- 4029583	14/06/77	None	
GB-A- 2075362	18/11/81	FR-A- 2480606 JP-A- 56147710 DE-A- 3115608 US-A- 4384954 JP-A- 56147711 JP-A- 57056038 JP-A- 57056039 JP-A- 57075141	23/10/81 16/11/81 18/03/82 24/05/83 16/11/81 03/04/82 03/04/82 11/05/82
US-A- 4118316	03/10/78	None	
US-A- 4140653	20/02/79	None	
FR-A- 2462183	13/02/81	DE-A- 2930516 JP-A- 56021643	12/02/81 28/02/81

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For more details about this annex :  
see Official Journal of the European Patent Office, No. 12/82

## INTERNATIONAL RECHERCHENBERICHT

Internationales Aktenzeichen PCT/DE 83/00056

## I. KLAFFIKATION DES ANMELDUNGSGEGENSTANDS (bei mehreren Klassifikationssymbolen sind alle anzugeben)

Nach der internationalen Patentklassifikation (IPC) oder nach der nationalen Klassifikation und der IPC

Int.Kl.<sup>3</sup> B 01 D 15/08; B 01 J 20/30; G 01 N 31/06

## II. RECHERCHIERTE SACHGEBiete

Recherchierte Mindestprüfstoff\*

Klassifikationssystem	Klassifikationssymbole
Int.Kl. <sup>3</sup>	B 01 D; B 01 J
Recherchierte nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Sachgebiete fallen <sup>4</sup>	

## III. EINSCHLAGIGE VERÖFFENTLICHUNGEN\*

Art <sup>5</sup>	Kennzeichnung der Veröffentlichung, soweit erforderlich unter Angabe der maßgeblichen Teile <sup>6</sup>	Betr. Anspruch Nr. <sup>6</sup>
X	DE, A, 2601930 (U.K.A.E.A.) 21. Juli 1977, siehe Seite 13, Zeile 12 - Seite 19, Zeile 22; Seiten 31-34, Beispiele 9-10 --	1,2,9,16, 17
Y	US, A, 4029583 (HO.CHANG) 14. Juni 1977, siehe Spalte 4, Zeile 5 - Spalte 16, Zeile 47 --	1,9-18
Y	GB, A, 2075362 (KURAPAY) 18. November 1981, siehe Seite 1, Zeilen 42-53, Zeile 62; Seite 4, Beispiel 1; Seite 7, Beispiel 8 Seite 10, Ansprüche 1-25 --	1-6,9-18
A	US, A, 4118316 (TALLEY) 3. Oktober 1978, siehe Spalten 8-12; Ansprüche 1-17 --	1,9,10, 16-18
A	US, A, 4140653 (IMURA) 20. Februar 1979, siehe Spalten 6-8; Ansprüche 1-9 --	1,9,11 --

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"X" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann nicht als neu oder auf erfundenscher Tätigkeit beruhend betrachtet werden

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"8" Veröffentlichung, die Mitglied derselben Patentfamilie ist

## IV. BESCHEINIGUNG

Datum des Abschlusses der internationalen Recherche <sup>8</sup>	Absendedatum des internationalen Recherchenberichts <sup>9</sup>
17. Juni 1983	15 JUL 1983
Internationale Recherchenbehörde Europäisches Patentamt	Unterschrift des bevollmächtigten Bediensteten G.L.M. Kruydenberg

## III. EINSCHLAGIGE VERÖFFENTLICHUNGEN (FORTS.) (G VON BLATT 2)

Art*	Kennzeichnung der Veröffentlichung, * soweit erforderlich unter Angabe der maßgeblichen Teile *	Betr. Anspruch Nr *
A	FR, A, 2462183 (MERK PATENT) 13. Februar 1981, siehe Seiten 25-26; Ansprüche 1-3	1, 9, 12

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Die Angaben über die Familienmitglieder entsprechen dem Stand der Datei des Europäischen Patentamts am 12/07/83

Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

Im Recherchenbericht angeführtes Patentdokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
DE-A- 2601930	21/07/77	Keine	
US-A- 4029583	14/06/77	Keine	
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FR-A- 2462183	13/02/81	DE-A- 2930516 JP-A- 56021643	12/02/81 28/02/81

Für nähere Einzelheiten zu diesem Anhang :  
siehe Amtsblatt des Europäischen Patentamts, Nr. 12/82